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Call admission algorithms in multi-service and multi-class ATM Network

S.Hamma^a G.Hébuterne^b

^aInstitut de Recherche en Communications et en Cybernétique de Nantes
Rue Christian Pauc BP 50609 44306 Nantes cedex 3 France

Salima.Hamma@ircryn.ec-nantes.fr

^bInstitut National des Télécommunications
Département Réseaux et Services de Télécommunications
9 Rue Charles Fourier 91011 Evry Cedex France
Gerard.Hebuterne@int-evry.fr

ABSTRACT

The introduction of new ATM service categories increases the benefits of ATM, making the technology suitable for a virtually unlimited range of applications. Connection Admission Control (CAC) is defined as the set of actions taken by the network during the call (virtual connection) set-up phase, or during call re-negotiation phase, to determine whether a connection request can be accepted or rejected. Network resources (port bandwidth and buffer space) are reserved to the incoming connection at each switching element traversed, if so required, by the service category. The major focus of this paper is call admission in the context of multi-service, multi-class ATM networks. Several strategies suggesting rules on bandwidth sharing are found in the literature. This study investigates particularly the Complete Sharing approach. Two service categories are concerned, namely, Constant Bit rate/Deterministic Bit Rate (CBR/DBR) and Variable Bit Rate/Statistical Bit Rate (VBR/SBR). Each service category is represented by a set of call classes corresponding to different bandwidth needs. We propose two algorithms to solve the underlying Markovian system: Product-form and Recursive solutions. A performance study based on the latter algorithm is implemented. We analyze the results of this very sharing strategy and set the not-to-violate limits for a beneficial use of it.

Keywords: ATM, CAC, Complete Sharing, blocking probability.

1. INTRODUCTION

Asynchronous Transfer Mode (ATM) technology is used in telecommunication networks environment. It transport voice, video and data traffic. So, both utilisation and management of network resources must be studied at different levels. Moreover, ATM used statistical multiplexing which allow sources using the silent period (of inactive sources) to send their traffic. In order to exploit this advantage, it is necessary to know the sources behavior and the traffic they generate. This is relatively easy for the voice sources, a little less for the compressed video sources with random input rate, but that becomes very difficult for the data sources whose incoming rate is very variable.

The traffic in the ATM network is observed on three different levels. The connection level, burst level and cell level which are illustrated by the figure 1:

- **Connection level:** a connection is the first level of scales of time hierarchy which is of about a minute. Some connections requests (or calls) cannot all be satisfied, they are thus rejected. The calls rejection rate, called Grade of service (GoS) is the principal criterion of performance on connection level.
- **burst level:** is an intermediate entity between connection and cell level. It characterizes the sporadic nature of the traffic which results in active and silent periods. The cells are sent in bursting form during the active period whereas no cell is sent during the silent period.

- **Cell level:** is a data unit used to transmit traffic users. The scales of time associated with this level is about millisecond or microsecond. The most important quality of service (QoS) parameters are loss rate, delay and jitter.

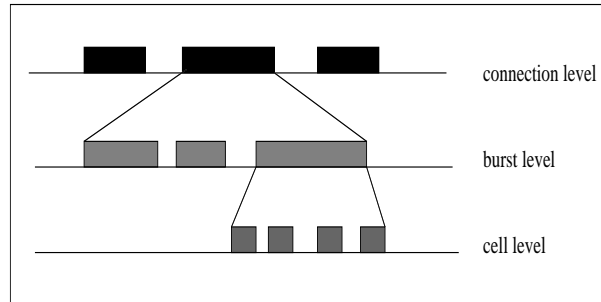


Figure 1. the hierarchy of the levels: connection, burst and cell

In this study, we are interested in connection level. The acceptance of a new connection means the establishment of a virtual circuit (VC) on which resources (i.e. bandwidth and memory) are reserved for all the duration of the call. Once the connection is established, the network must respect the contract of quality of service negotiated with the source. According to the type of application, Standardization organizations, both IUT-T and the ATM Forum, have defined traffic contracts that concerns different quality of service needs. The statistical multiplexing allows a better network resources sharing, but requires certainly an efficient management of the bandwidth and traffic control. The CAC (Connection Admission Control) raises great discussions a great interest by network researchers community. The rest of the paper is organized as follows: chapter 2 describes the traffic control in ATM and enumerate various call admission strategies. In chapter 3, we present the context of the study, describe the model and gives a markov chain example. The algorithm we have proposed are described in chapter 4. Some numerical results and analysis are given in chapter 5. At last we conclude this study by giving the perspectives for next work on the subject.

2. TRAFFIC CONTROL

There is no flow control in ATM network, preventive control is thus required. It allows to prevent the deterioration of the quality of service relating to the calls in progress and control that sources respect contracts of traffic they subscribes for. Mechanisms ensuring these two functionalities are the CAC (Connection Admission Control) and the UPC (User Parameter Control). The CAC procedure is carried out during the connection establishment phase which allows to determine if the call can be accepted or not. The UPC procedure operates on the cell level which guarantee the contract of quality of service subscribed by the user. In this paper, we focus on resources sharing problem in a multi-service and multiclass environment. Two kind of services are considered:

- CBR (Constant Bit Rate)/DBR (Deterministic Bit Rate) : the peak rate determines resources required by sources. The real times applications such as interactives multimedia applications, videoconference or circuit emulation are standard application examples.
- VBR (Variable Bit Rate)/SBR (Statistical Bit Rate) : the parameters identifying this type of service are peak rate (PCR), the sustainable rate (SCR) and the maximum burst size. It allows better resources share compared to CBR (DBR). The network guarantees to the sources the mean input rate or an equivalent one calculated using an appropriate algorithms.²

Both DBR and SBR contract correspond to the sources called input rate guaranteed.

2.1. Call admission strategies

The different strategies identify the link bandwidth sharing rules between the sources. Let us assume multi-server link of capacity C shared by K incoming traffic classes, $b = \{b_1, b_2, \dots, b_K\}$ and $n = \{n_1, n_2, \dots, n_K\}$ respectively the required capacity vector number of calls of each class. The strategies of call acceptance given in literature are as follows⁶:

- The complete sharing method: is the policy which accepts a connection as long as the residual capacity is sufficient. It results in the following condition: $b_k + \sum_{i=1}^K n_i b_i \leq C$ where b_k required resource and K is the number of call classes.
- The complete partitioning method: it is the policy which accepts a call of class k if the residual capacity for this class is sufficient: $(n_k + 1) b_k \leq C_k$ where C_k is a bandwidth partition of class k calls and $\sum_{i=1}^K C_i = C$
- The partial partitioning method: is a similar policy with the preceding one except that the number of bandwidth partition is different of that of the number of call classes. A call of class k belonging to the group of classes P_l is accepted if it satisfies the following condition: $b_k + \sum_{i \in P_l} n_i b_i \leq C_l$
- The threshold policies: this policy limits the number of calls of each class. Contrary to the precedent policy, the sum of the allocated partitions can exceed the total link capacity. A call of class k is accepted if it satisfies the following rule: $(n_k + 1) b_k \leq C_k$ and $b_k + \sum_{i=1}^K n_i b_i \leq C$
- The trunk reservation: allows to overcome possible unfairness induced by the complete sharing strategy, which is the cause of increased blocking rates. After call admission of class k , the residual bandwidth must be equal to θ_k . The threshold choice makes it possible to control the blocking probabilities: $b_k + \sum_{i=1}^K n_i b_i \leq C - \theta_k$
- The equalizing policy: is considered as a particular case of precedent policy where θ_k is such that $\theta_k = \max\{b_k\}, 1 \leq k \leq K$. This choice allows to equalize the blocking probabilities of all the classes.

3. MODEL AND ASSUMPTIONS

Let PCR (resp. SCR) denote the amount of bandwidth consumed by DBR (resp. SBR) traffics.

3.1. The multi-service system

The paper focuses on the evaluation of the blocking probability in a multi-service system. We have considered two kind of services DBR and SBR. Each one is represented by a group of sources with different traffic parameters. The call admission policy we considered is complete sharing strategy. Based on the preliminary studies, the cell level QoS is assured according to the following equations:

$$\sum PCR \leq \rho_1 C \quad (1)$$

$$\sum SCR \leq \rho_2 [C - \sum PCR] \quad (2)$$

This may delimit an area in which both DBR and SBR traffic are QoS guaranteed. Let us denote the quantity $\sum (PCR + SCR)$ as the total load. It is kept less than $(\rho_2 + (1 - \rho_2)\rho_1) C < 1$. Previous studies have shown that a good choice could be $\rho_1 = 0.4, \rho_2 = 0.8$. So, total load is less than 0.88.

3.2. The model description

Let us denote Ω the state space acceptable by resource sharing policy:

$$\Omega = \{(n, m) \mid (0, 0) \leq (n, m) \cdot (d_1, d_2) \leq (C_1, C_2)\}$$

Where n and m are respectively DBR and SBR call number vectors: $n = \{n_1, n_2, \dots, n_l\}$ and $m = \{m_1, m_2, \dots, m_p\}$, with n_i or m_i is respectively DBR and SBR call number of class i using bandwidth resource. d_1 and d_2 are respectively DBR and SBR required capacity: $d_1 = \{d_{11}, d_{12}, \dots, d_{1l}\}$, $d_2 = \{d_{21}, d_{22}, \dots, d_{2p}\}$. We can also write $C_1 = \rho_1 C$, $C_2 = \rho_2 [C - n d_1]$ where C_1, C_2 gives the maximal capacity respectively of DBR and SBR traffic. Thus:

$$(n, m) \cdot (d_1, d_2) = \left(\sum_{i=1}^l n_i d_{1i}, \sum_{j=1}^p m_j d_{2j} \right)$$

where l is a number of DBR sources (classes) with offered load $a_{i,D} = \frac{\lambda_{i,D}}{\mu_{i,D}}$, where $\lambda_{i,D}$ is incoming call admission request rate and $\mu_{i,D}^{-1}$ is the mean service time of DBR communication of class i . p is a number of SBR sources (classes) with offered load $a_{i,S} = \frac{\lambda_{i,S}}{\mu_{i,S}}$, where $\lambda_{i,S}$ is incoming call admission request rate and $\mu_{i,S}^{-1}$ is the mean service time of SBR communication of class i .

The state distribution of Ω set is given by the following product form:

$$P(n, m) = \prod_{i=1}^l \frac{a_{i,D}^{n_i}}{n_i!} \prod_{j=1}^p \frac{a_{j,D}^{n_j}}{n_j!} G^{-1}(\Omega) \quad (3)$$

$$G(\Omega) = \sum_{(n,m) \in \Omega} \prod_{i=1}^l \frac{a_{i,D}^{n_i}}{n_i!} \prod_{j=1}^p \frac{a_{j,D}^{n_j}}{n_j!} \quad (4)$$

The major performance parameter is the blocking probability denoted $P_{b(i,j)}$ which gives the probability that the DBR or SBR call of class i (needed b_i bandwidth units) is blocked. We can write it as follows:

$$P_{b(i,j)} = \sum_{(n,m) \in B_{i,j}^+} P(n, m) \quad (5)$$

where:

$$B_{i,j}^+ = \{(n, m) \in \Omega \mid (n_i^+, m_j^+) \notin \Omega\} \quad (6)$$

such as:

$$n_i^+ = \{n_1, n_2, \dots, n_i + 1, \dots, n_l\} \quad \text{and} \quad m_j^+ = \{n_1, n_2, \dots, n_j + 1, \dots, n_p\}$$

Equation (5) becomes:
$$P_{b(i,j)} = 1 - \sum_{(n,m) \notin B_{i,j}^+} P(n, m) = 1 - \frac{\overline{G(B_{i,j}^+)}}{G(\Omega)}$$

with $G(\Omega) = G(C, T)$:

$$P_{b(i,j)} = 1 - \frac{G(C - d, T)}{G(C, T)} \quad (7)$$

where: $C = (C_1, C_2)$,

$$T = (l, p)$$

$$d = (d_i, d_j) \quad \text{such as:} \quad d_i = \begin{cases} d_{1i} & \text{si } 1 \leq i \leq l \\ 0 & \text{si } i = 0 \end{cases} \quad d_j = \begin{cases} d_{1j} & \text{si } 1 \leq j \leq p \\ 0 & \text{si } j = 0 \end{cases}$$

Thus, the problem now is computing the $G(C, T)$ constant.

3.3. The Markov Chain example

The markov chain illustrated by the figure 2 shows the multiplexing of DBR and SBR traffic with input rate requirement $d_1 = d_2 = 1$ unit. The total capacity of the shared link is 9 units. The incoming DBR and SBR call bit rate are respectively λ_1 et λ_2 . The service bit rate for DBR and SBR traffic is respectively μ_1 and μ_2 .

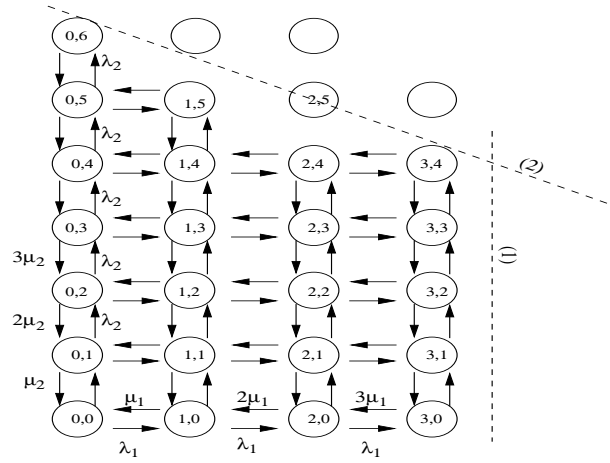


Figure 2. Markov Chain example, $C = 8, \rho_1 = 0.4, \rho_2 = 0.8$

4. THE PROPOSED ALGORITHMS

We propose two algorithms, one based on a matrix representation of G (product form solution) and the second one is a recursive solution based on the state space reduction.

4.1. The first algorithm

The following algorithm is an extension of the Kaufman-Roberts algorithm.⁴ It is developed for the complete sharing of the bandwidth between different classes calls (different bits rate). It consists of a matrix representation G for dimension 4 of which each element is computed iteratively.

$$\begin{aligned}
G(J, 1_1) &= \sum_{n_l=0}^{v/d_{11}} \frac{a_{1,D}^{n_l}}{n_l!} & 1_1 &= (1, 0) \\
G(J, 1_2) &= \sum_{n_p=0}^{w/d_{12}} \frac{a_{1,S}^{n_p}}{n_p!} & J &= (v, w) \\
G(J, R_1) &= \sum_{n_l=0}^{v/d_{11}} \frac{a_{1,D}^{n_l}}{n_l!} G(J - D_1, R_1 - 1_1) & v &= \{0, \dots, \rho_1 C\} \\
& & w &= \{0, \dots, \rho_2 [C - v]\} \\
& & 1_2 &= (0, 1) \\
& & D_1 &= (n_l \, d_{1l}, 0) \\
& & R_1 &= (x, 0) \\
& & x &= \{1, \dots, l\}
\end{aligned} \tag{8}$$

$$\begin{aligned}
G(J, R_2) &= \sum_{n_p=0}^{w/d_{12}} \frac{a_{1,S}^{n_p}}{n_p!} G(J - D_2, R_2 - 1_2) \\
D_2 &= (0, n_p d_{2p}) \\
R_2 &= (0, y) \\
y &= \{1, \dots, p\} \\
\\
G(J, R) &= \sum_{n_l=0}^{v/d_{11}} \sum_{n_p=0}^{w/d_{12}} \frac{a_{1,D}^{n_l}}{n_l!} G(J - D_1, R - 1_1) \frac{a_{1,S}^{n_p}}{n_p!} G(J - D_2, R - 1_2) \\
R &= (x, y) \\
x &= \{1, \dots, l\} \\
y &= \{1, \dots, p\} \\
G(J, 0_1) &= 1 \\
G(J, 0_2) &= 1 \\
0_1 &= (0, y) \\
0_2 &= (x, 0)
\end{aligned}$$

The number of combinations in J denoted X is cardinal of state Markov chain number: $X = (N + 1) M$ where : $N = C_{1max}$, maximum capacity which can be used by DBR traffic. $M = C_{2max}$, maximum capacity which can be used by SBR traffic knowing that DBR traffic null. The number of combinations in T denoted Y is given by: $l * p + (l + p)^2$

Thus, the matrix X^*Y element is recursively calculated. However, this leads to accuracy and excessive run time problems when the capacity of the link grows and the number of DBR and SBR sources become considerable. In order to avoid such difficulties, we have developed recursive algorithm with two dimensions instead of four dimensions as in previous solution.

4.2. The second algorithm

The main idea is to use two random variables denoted C_1 and C_2 where $C_1 = n d_1$, is a total number of bandwidth units occupied by DBR traffic and $C_2 = n d_2$, is a total number of bandwidth units occupied by SBR traffic. Let us assume $C = (C_1, C_2)$. The distribution function of C is given by:

$$q(c) = \sum_{(n,m) \in S(c)} P(n, m) \quad (9)$$

Where $S(c) = \{(n, m) \mid (n \cdot d_1, m \cdot d_2) = (c_1, c_2)\}$

From equation (9) we can write the following equations:

$$\begin{aligned}
c q(c) &= \sum_{(n,m) \in S(c)} c P(n, m) \\
&= \sum_{(n,m) \in S(c)} [\sum_{i=1}^l n_i d_{1i} + \sum_{j=1}^p m_j d_{2j}] P(n, m) \\
&= \sum_{(n,m) \in S(c)} [\sum_{i=1}^l n_i d_{1i} P(n, m)] + [\sum_{j=1}^p m_j d_{2j} P(n, m)] \\
&= \sum_{i=1}^l d_{1i} \sum_{(n,m) \in S(c)} n_i P(n, m) + \sum_{j=1}^p d_{2j} \sum_{(n,m) \in S(c)} m_j P(n, m)
\end{aligned}$$

$$\begin{aligned}
\text{However, } \sum_{(n,m) \in S(c)} n_i P(n, m) &= \sum_{(n,m) \in S(c)} n_i \prod_{q=1}^l \frac{a_{q,D}^{n_q}}{n_q!} \prod_{j=1}^p \frac{a_{j,D}^{n_j}}{n_j!} G^{-1}(\Omega) \\
&= \sum_{(n,m) \in S(c)} n_i \frac{a_{i,D}^{n_i}}{n_i!} \prod_{q=1, q \neq i}^l \frac{a_{q,D}^{n_q}}{n_q!} \prod_{j=1}^p \frac{a_{j,D}^{n_j}}{n_j!} G^{-1}(\Omega) \\
&= \sum_{(n,m) \in S(c)} a_{i,D} \frac{a_{i,D}^{n_i-1}}{(n_i-1)!} \prod_{q=1, q \neq i}^l \frac{a_{q,D}^{n_q}}{n_q!} \prod_{j=1}^p \frac{a_{j,D}^{n_j}}{n_j!} G^{-1}(\Omega) \\
&= \sum_{(n,m) \in S(c)} a_{i,D} P(n - 1_i, m) \\
&= a_{i,D} \sum_{(n,m) \in S(c-d_{1i})} P(n, m) \\
&= a_{i,D} q(c - d_{1i})
\end{aligned}$$

In the same way:

$$\begin{aligned}\sum_{(n,m) \in S(c)} m_j P(n,m) &= \sum_{(n,m) \in S(c)} a_{j,S} P(n,m-1_j) \\ &= a_{j,S} \sum_{(n,m) \in S(c-d_{2j})} P(n,m) \\ &= a_{j,S} q(c-d_{2j})\end{aligned}$$

Thus,

$$c q(c) = \sum_{i=1}^l d_{1i} a_{i,D} q(c-d_{1i}) + \sum_{j=1}^p d_{2j} a_{j,S} q(c-d_{2j}) \quad (10)$$

The algorithm is as follow:

1. $g(0,0) = 1$; $g(c_1, c_2) = 0$ si $c_1 < 0$ ou $c_2 < 0$
2. for $c_1 = 1, \dots, C_{1max}$ $C_{1max} = \rho_1 C$
for $c_2 = 1, \dots, C_{2max}$ $C_{2max} = \rho_2 [C - c_1]$

$$g(c_1, c_2) = \frac{1}{c_1 + c_2} [\sum_{i=1}^l d_{1i} a_{i,D} g(c-d_i^{(1)}) + \sum_{j=1}^p d_{2j} a_{j,S} g(c-d_j^{(2)})]$$

$$c = (c_1, c_2), \quad d_i^{(1)} = (d_{1i}, 0), \quad d_j^{(2)} = (0, d_{2j})$$

3. $G = \sum_{c_1=0}^{C_{1max}} \sum_{c_2=0}^{C_{2max}} g(c_1, c_2)$
4. for $c_1 = 1, \dots, C_{1max}$ $C_{1max} = \rho_1 C$
for $c_2 = 1, \dots, C_{2max}$ $C_{2max} = \rho_2 [C - c_1]$

$$q(c_1, c_2) = \frac{g(c_1, c_2)}{G}$$

5. Compute the blocking probabilities for the two kind of traffic (DBR and SBR).

4.3. Blocking probabilities

The blocking probabilities of DBR calls denoted B_1 and SBR calls denoted B_2 are given by the following equations:

$$B_1 = \sum_{c_2=0}^{C_{max}-C_{1max}} q(C_{1max}, c_2) + \sum_{c_1=0}^{C_{1max}-1} \sum_{\lfloor \rho_2 [C-(c_1+1)]+1 \rfloor}^{C_{2max}} q(c_1, c_2) \quad (11)$$

$$B_2 = \sum_{c_1=0}^{C_{1max}} q(c_1, C_{2max}) \quad (12)$$

Where : $C_{1max} = \lfloor \rho_1 C \rfloor$, $C_{2max} = \lfloor \rho_2 (C - c_1) \rfloor$, $C_{max} = C_{1max} + \lfloor \rho_2 (C - c_{1max}) \rfloor$

The blocking probabilities of respectively DBR and SBR traffic classes is denoted B_{1i} , $i = \{1, \dots, l\}$ and B_{2j} , $j = \{1, \dots, p\}$. They are calculated as follows:

$$B_{1i} = \sum_{c_2=0}^{C_{max}-C_{1max}} \sum_{j=0}^{\min(C_{1max}, d_{1i}-1)} q(C_{1max}-j, c_2) + \sum_{c_1=0}^{C_{1max}-1} \sum_{j=0}^{\min(c_1, d_{1i}-1)} \sum_{\lfloor \rho_2 [C-(c_1+1)]+1 \rfloor}^{C_{2max}} q(c_1-j, c_2) \quad (13)$$

$$B_{2j} = \sum_{c_1=0}^{C_{1max}} \sum_{i=0}^{\min(C_{2max}, d_{2j}-1)} q(c_1, C_{2max}-i) \quad (14)$$

5. RESULTS AND DISCUSSIONS

In this paper, we propose to study the behavior of the system solved by the recursive algorithm describes previously. We consider several system configurations in terms of the total offered load bandwidth requested by each call. We are also interested in the evaluation of the blocking probabilities according to the ratio of the traffic offered DBR and the traffic offered SBR.

Because the analytical solution uses the values of $a_{i,x} = \frac{\lambda_{i,x}}{\mu_{i,x}}$, $x = D, S.$, and not the individual values, an important step is to confirm this property. This is done through a simulation study. The performance evaluation carried out are given in the following paragraphs.

The simulation model studied corresponds to a queue $M_D + M_S/M/c/c$. The Poisson arrivals correspond to DBR and SBR calls. The service time (of the communication) is exponential. The total capacity is given by: $C_{max} = C_{1max} + \lfloor \rho_2(C - C_{1max}) \rfloor$ where $C_{1max} = \lfloor \rho_1 C \rfloor$

C is the total link capacity, ρ_1 and ρ_2 is respectively DBR traffic load and SBR traffic load

The simulator is developed in C language, it corresponds to events simulation. Each one is described by its arrival date, type of service, class, type of event (Arrival or Departure) and duration. This simulation allows to validate the recursive solution and to evaluate the blocking probabilities according to the ratio of service rates.

5.1. Blocking probabilities evolution

We consider two kinds of services (DBR et SBR) which share the same ATM transmission link with capacity of 25 Mb/s. For each service, we assume two kind of calls. One called class 1 correspond to high incoming bit rate and other called class 2 with low incoming bit rate. These rates are given in unit (1 unit=100Kb/s). The test parameters are given in table 1. The total offered traffic load is 0.7,0.8 and 0.9.

	DBR traffic	SBR traffic
class 1	5 units	5 units
class 2	1 unit	1 unit

Table 1. input rate of two kind of calls

The figures 3 and 4 illustrate the behavior of the blocking probabilities of each call according to the DBR load. A first obvious remark we can made is the increase in the probabilities of call rejection when the total load offered increases. We can also note that the rejection probability is high for calls requiring a greater bandwidth capacity (typically calls of class 1). Moreover, the probability of blocking DBR calls decreases slightly when their offered traffic load is low (figure 3). When the offered traffic load becomes more important, the call rejections are also more important. Maximum rejection probability for DBR sources is reached when offered load is 0.4 for any total load (DBR+SBR) values. Whereas, blocking probability of SBR calls decreases when the DBR offered load increases, i.e. that of SBR decreases. The reduction is more sensitive when DBR load increases.

5.2. Impact of the DBR traffic

The figures 5 and 6 illustrate the impact of traffic DBR (SBR offered load fixed) on respectively DBR and SBR calls rejections. The behavior is studied for two different configurations. The first configuration relates to SBR calls load 0.4 (low). The second relates to SBR calls load 0.8 (high). In the first case, the probability of rejection increases quasi linearly when DBR load increases. The maximum increase reaches at maximum load DBR=0.6. This behavior is identical for two traffic classes. However, blocking probability is higher when the bandwidth capacity requirement is high, i.e. class 1. In the second case, rejection probabilities is higher because it is not consider only the states DBR border as is almost the case in preceding configuration but also probability in SBR borders since load SBR is 0.8 for all test. So, the degradation observed corresponds to the increase of DBR load in the system.

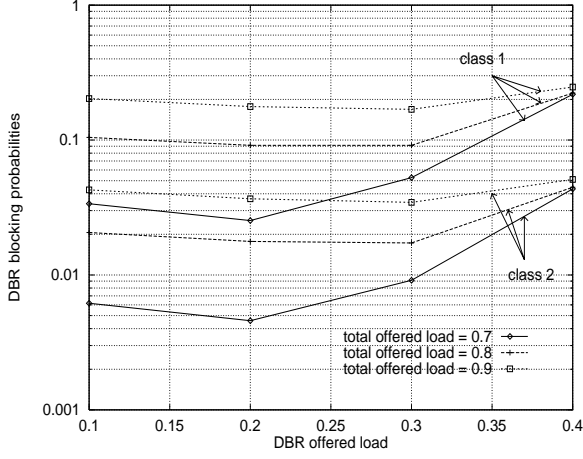


Figure 3. DBR blocking probabilities for different offered traffic load, $d_1 = \{5, 1\}$, $d_2 = \{5, 1\}$

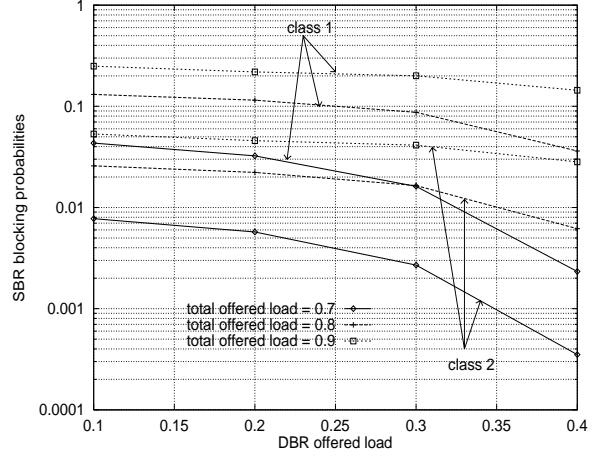


Figure 4. SBR blocking probabilities for different offered traffic load, $d_1 = \{5, 1\}$, $d_2 = \{5, 1\}$

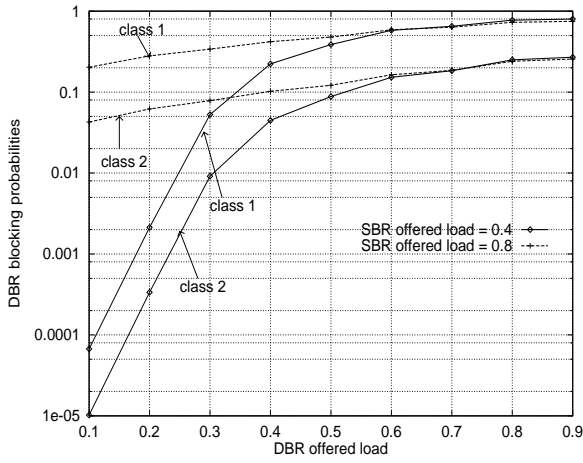


Figure 5. DBR traffic impact, $d_1 = \{5, 1\}$, $d_2 = \{5, 1\}$

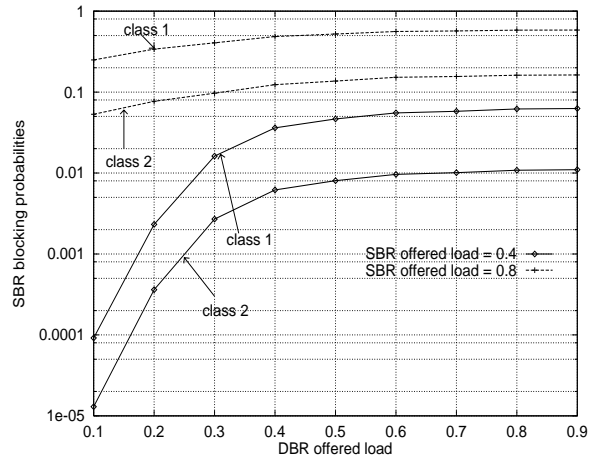


Figure 6. SBR traffic impact, $d_1 = \{5, 1\}$, $d_2 = \{5, 1\}$

5.3. Impact of the SBR traffic

The figures 7 and 8 show the impact of SBR traffic on the rejection probabilities for both DBR and SBR calls. We have assumed a fixed DBR load and a variable SBR load. Two different values of DBR load are used, namely low DBR load (0.2) and high DBR load (0.4). In case of low DBR load, the figure 7 shows the influence of the SBR load on the rejection probabilities of the DBR calls which is effective only when this load is higher than 0.3. For a lower load, this loss is constant since limit SBR not being reached yet. In the second case, the blocking probability of DBR traffic are constant since the SBR load is less than 0.4. The system is then mostly saturated by DBR calls. We achieve the SBR limit gradually with the SBR load increase as shown in figure 8.

5.4. Impact of the traffic ratio

We consider the multiplexing of DBR and SBR sources. Each one requires a capacity of 1 unit (100Kb/s) for a total capacity of 25Mb/s (250 units). Let us denote A_1 the traffic offered by DBR sources and A_2 , the traffic offered by SBR sources such as:

$$A_1 = \sum_{i=1}^l a_{i,D} d_{1i} \quad \text{where} \quad a_{i,D} = \frac{\lambda_{i,D}}{\mu_{i,D}} \quad l: \text{ is a number of DBR sources}$$

$$A_2 = \sum_{j=1}^p a_{j,S} d_{2j} \quad \text{where} \quad a_{j,S} = \frac{\lambda_{j,S}}{\mu_{j,S}} \quad p: \text{ is a number of SBR sources}$$

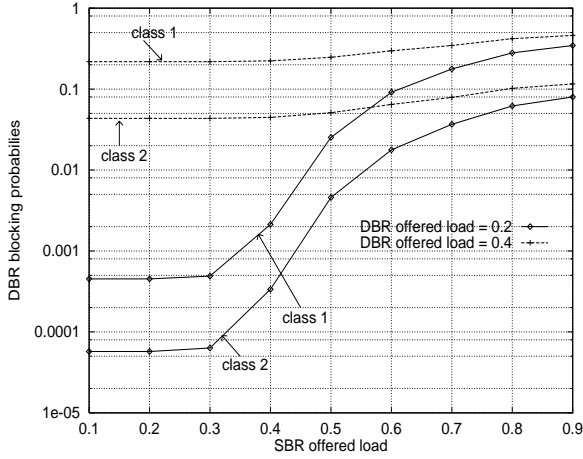


Figure 7. SBR traffic impact, $d_1 = \{5, 1\}, d_2 = \{5, 1\}$

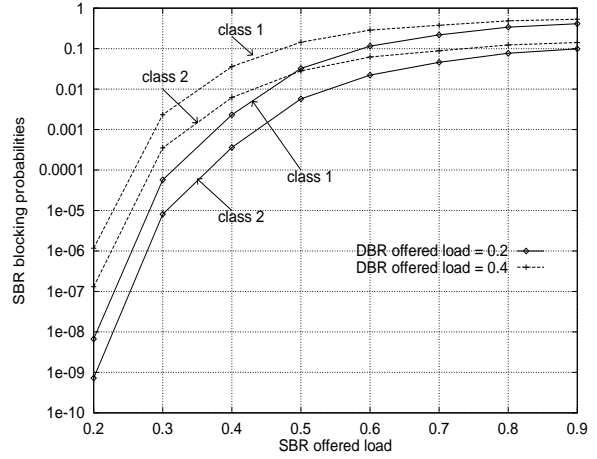


Figure 8. SBR traffic impact, $d_1 = \{5, 1\}, d_2 = \{5, 1\}$

We try here to answer (illustrated by a curve) to the following questions:

1. What is the evolution of the losses according to the traffic ratio $\frac{A_1}{A_2}$?
2. What is the variation of the call rejection related to two types of traffic and according to the ratio $\frac{A_1}{A_2}$ and to the input rate needed by each one ?

The answer to first question is illustrated through the figure 9 which traces the evolution of the loss for increasing loads. First, we observe that the higher the ratio $\frac{A_1}{A_2}$ (i.e. traffic DBR increases and SBR decreases), the lower the rejections probabilities for the two types of services. This behavior is true as long as the proportion of traffic offered does not exceed 0.6, i.e. when traffic DBR does not exceed 60% of offered traffic SBR. In case of this ratio is higher to 0.6, the blocking probability of DBR sources increases very quickly (due to the limitation of allowed DBR load). If we consider the quality of service for each type of traffic, in a configuration of complete bandwidth sharing, its maximum is reached when $\frac{A_1}{A_2}$ is about 0.6.

In order to answer the second question, we consider multiplexing of DBR and SBR sources with different bandwidth requirements (in opposite of the preceding case). The figure 10 illustrates the behavior of a system induced by such choices.

When the bandwidth required by DBR traffic is higher than those of SBR (typically $d_2 = 1$ and $d_1 = 2, 3, 4, 5$), the ratio of the blocking probabilities is proportional to the number of units required by DBR. On the other hand, when the requirements are higher for SBR (typically $d_1 = 1$ and $d_2 = 2, 3, 4, 5$), the ratio of the blocking probabilities is inversely proportional to the number of units required by SBR. Moreover, this ratio is constant for any value of ratio $\frac{A_1}{A_2} \leq 1$.

5.5. Impact of service rate ratio

The product form as well as the recursive solution let suppose that the behavior of the system depends only on the $\frac{\lambda}{\mu}$ ratio and not of λ and μ separately. In this paragraph, we look at the influence of DBR and SBR service rates on the system behavior. Four experiences were conducted as resume in table 2. The figures 11 and 12 show respectively results related to test2 and test3. We can draw two conclusions. First, simulations validate the Markovian model given in the previous paragraph, confirming that blocking probabilities do not dependent on the service rate ratio.

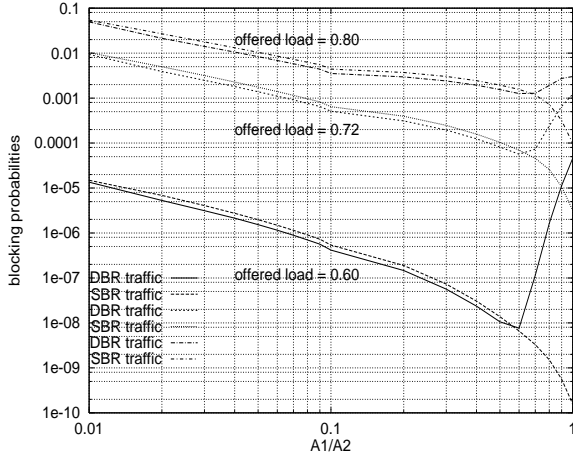


Figure 9. blocking probabilities as function of $\frac{A_1}{A_2}$, $d_1 = 1$, $d_2 = 1$

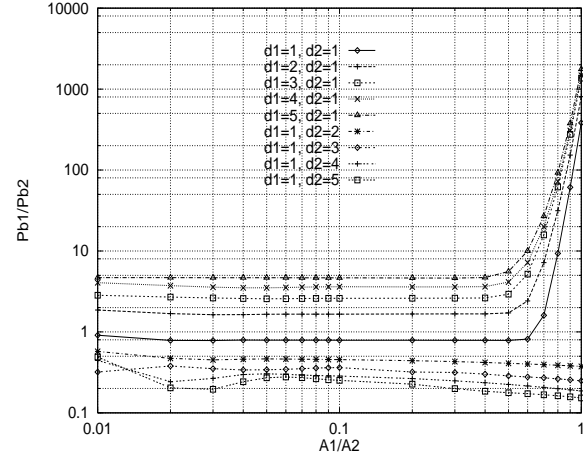


Figure 10. rejected calls variation as function of $\frac{A_1}{A_2}$ et des $d_i, i = 1, 2$

Parameters	test1	test2	test3	test4
λ_D	30	30	30	60
μ_D	1	1	1	1
d_1	1	2	1	1
λ_S	$20 \mu_S$	$20 \mu_S$	$30 \mu_S$	$120 \mu_S$
μ_S	$\mu_D/ratio$	$\mu_D/ratio$	$\mu_D/ratio$	$\mu_D/ratio$
d_2	5	5	5	1
Load	0.56	0.64	0.72	0.76

Table 2. Test parameters

6. CONCLUSIONS AND PERSPECTIVES

This paper deals with calls acceptance problem in multiservices and multiclass mode in ATM network. Appropriate algorithms describe how the bandwidth transmission link is shared between various sources. In this study, the focus is restricted to the complete sharing strategy, when two different service levels are mixed, respectively a constant service rate (DBR) and a variable, but controlled, one (SBR). Previous studies at the cell level have defined rules for the simultaneous fulfilment of QoS requirements of both DBR and SBR. Based on these results, we propose two algorithms allowing the resolution of the markovian system managing the various calls. Our proposal take into account the different resources requirements by each type of service. In other words, the model is valid whatever the number of classes associated with each category of service. The second algorithm is easier to implement as it reduces the state space needed for the mathematical resolution. The performance study allows to understand and analyze sharing mechanism, so as to define its limits and optimize its use. Especially, this allows to draw the following broad conclusions:

- when the traffic offered by DBR does not exceed 60% of the traffic offered by SBR, the blocking probability of the calls decreases, if the bandwidth requirements are equal for the two service categories or higher for DBR one.
- when the traffic offered by DBR is maximum equal to traffic offered by SBR, the probability decrease only if SBR traffic requirements are higher than those for DBR.
- the blocking probability of each category of service is proportional to the traffic required by those.

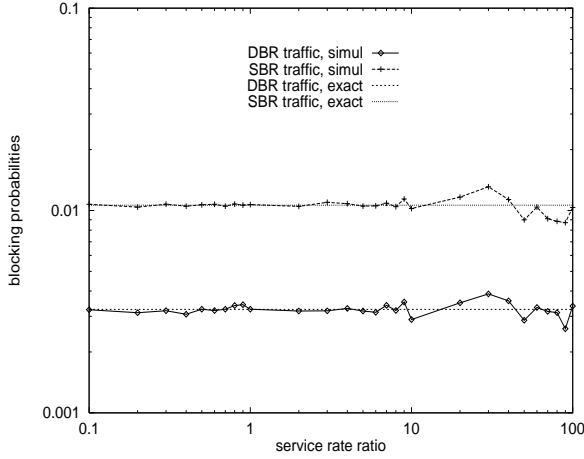


Figure 11. call rejection as function of $\frac{\mu_D}{\mu_S}$, test2

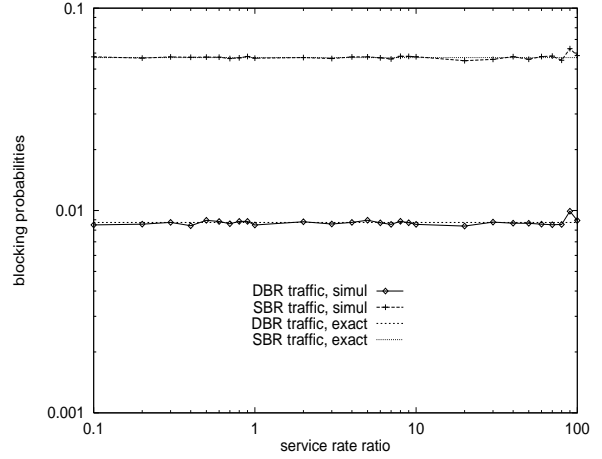


Figure 12. call rejection as function of $\frac{\mu_D}{\mu_S}$, test3

However, the sharing policy raises a fairness problem. The calls with higher input rate have a stronger probability of being refused. For this reason, this phenomenon should be controlled. This could be done, using the general approach of⁶:

- The first approach consists in using threshold algorithms with considering an equalization of the blocking probabilities. This equalization must take into account the asymmetry shown in first two equations given in the beginning of this paper.
- The second approach will consist in maximizing a global factor profit according to the estimated profits of each category as illustrated by the following equation: $G(B_D, B_S) = \sum_i \frac{\lambda_i(1-B_i)d_i}{\mu_i} X_i$ where $X_i, i = D, S$ are the profit associated to DBR and SBR services.

The question is here in the choice of B_i so that to optimize the global acceptance scheme.

This last approach can be less easy to realize and further studies remain to be lead in order to clarify these points.

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